

**Raptor Nesting Near Oil and Gas Development:
An Overview of Key Findings and Implications
for Management Based on Four Reports
by HawkWatch International**



Raptor Nesting Near Oil and Gas Development: An Overview of Key Findings and Implications for Management Based on Four Reports by Hawk Watch International



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This is an overview of key findings about the effectiveness of stipulations used to manage the potential effects of disturbance to raptor nesting in areas where oil and gas are being extracted from Bureau of Land Management (BLM) lands in Utah, Wyoming, and Colorado. These findings come from research by HawkWatch International, Inc. (HWI) and provide information for management decisions about land where oil and gas (OG) extraction occurs or might occur on public lands. HWI identified factors that fairly consistently are associated with increases or decreases in raptor nest use and activity.

This overview comprises information from the four BLM Technical Notes written by HWI.

- An Assessment of the Effects of Oil and Gas Field Activities on Nesting Raptors in the Rawlins, Wyoming and Price, Utah Field Offices of the Bureau of Land Management. TN-433

- Artificial Nest Structures as Mitigation for Natural-Gas Development Impacts to Ferruginous Hawks (*Buteo regalis*) in South-Central Wyoming. TN-434
- Accipiter Use of Pinyon–Juniper Habitats for Nesting in Northwestern Colorado. TN-435
- Recommendations for Improved Raptor Nest Monitoring in Association with Oil and Gas Development Activities. TN-436

The results of the projects will be most meaningful if read in full with the methodology and discussion offered by HWI.

The project was undertaken because of a paucity of information about the possible effects of OG operations and resource management on nesting raptors. BLM raptor management has included stipulations that restricted human activity near raptor nests during the raptor nesting season. The BLM and the Department of Energy (DOE), which provided financial support for the study, seek information that will contribute to enhancing OG extraction operations while providing environmental protection, including raptor conservation.

This project used historical data from Utah and Wyoming. The Price, Utah study area, as of 2006, contained more than 1,100 wells, in a nearly uniform distribution at a density of one per quarter section (160-acre spacing). Some development occurred closer to existing nests because the nest sites had not been discovered or because the land is administered by the State of Utah, without these stipulations. The Rawlins, Wyoming study area included more than 4,200 OG wells in 2006. Compared to the Price study area, wells at Rawlins were less regularly distributed; reaching densities of one well per quarter section (160-acre spacing) in some areas, but less dense elsewhere.

HWI compiled information from federal bureaus, state agencies, and industry, and determined how to evaluate the effectiveness of spatial and temporal buffer restrictions that have been applied within areas of OG extraction. HWI used the historical data to describe patterns of OG development relative to raptor nests, and to document changes in the distribution and breeding status of raptor nests relative to OG activities. HWI evaluated how these historical datasets were useful for quantifying the relationship between OG development and other human activities and nesting raptors. HWI assessed changes in Ferruginous Hawk (*Buteo regalis*) nesting success and productivity, and in use of artificial nest structures (ANSs), which had been erected to reduce the use by raptors of OG structures as nest substrates. Also, HWI studied *Accipiter* species' use of pinyon–juniper vegetation communities in the Piceance Basin of Colorado, described basic vegetation and landscape characteristics of nests, and offered recommendations about surveying for accipiter hawks in pinyon–juniper landscapes. Please read the HWI reports for details.

An Assessment of the Effects of Oil and Gas Field Activities on Nesting Raptors in the Rawlins, Wyoming and Price, Utah Field Offices of the Bureau of Land Management.

*Jeff P. Smith, Steve J. Slater,
and Mike C. Neal*

The goal was to assess protective spatial and temporal buffers and provide guidance to minimize potential disturbance to raptors nesting near OG activities.

HWI uses “development” to refer collectively to factors (e.g., wells and roads) associated with the development and maintenance of OG extraction. A nest cluster was a group of proximate individual nests that likely were alternative nests maintained by one pair using the immediate vicinity. The nest cluster associated with an individual breeding pair was a single sample unit.

Two overlapping classifications account for uncertainties inherent in the historical data about reproduction attempts and the status of nests. HWI conducted separate analyses to evaluate two categories of nest status:

The first category type was “used” = evidence of recent nest tending, occupation or actual breeding, or “unused” = no such evidence obtained.

The second category type was “active” = breeding attempt confirmed (i.e., egg or nestling), or “other” = all other cases, including some used (i.e., evidence of tending, but not actual breeding) and all unused classifications.

HWI measured the distance from a nest cluster centroid or an active nest to wells or roads and analyzed these distances relative to nest status categories. Most measurements including coverage of various vegetation types (e.g., black sagebrush, juniper) were made within two spatial scales: 0.8-km and 2.0-km of nests, to correspond to typical nest protections in the study areas, and to encompass the majority of the study species’ home ranges, respectively. HWI designated development “hotspots” as areas with well densities >0.6 per square km (>1.2 wells within a 0.8-km radius)

by 2006, and continual additional OG development since 1998.

The number of nest clusters of a species, number of well sites, and associated features varied depending on the relationships being analyzed. For many analyses the number was the sum of all the nests in all the years. HWI used standard statistical procedures and Geographic Information System (GIS) software to analyze spatial relationships among development and nest clusters. HWI used multiple regression to analyze the proportion of years nest clusters surveyed a minimum of 5 years were used during OG development and to investigate whether the status of nest cluster was affected by OG development.

Using data that resulted from analyzing relationships among nest cluster use and development and between nest cluster activity and development, HWI added vegetation and climate factors to determine the relationships between use, activity, and development, after accounting for the potential influence of vegetation and yearly climate. This modeling included combinations of parameters and predictor variables. They also modeled Ferruginous Hawk nest success and productivity, and nesting on ANSs relative to these variables and to nest accessibility. For each species and study area, HWI presented the top models (i.e., the most likely models based on accepted model selection procedures, given the data under consideration) from many possible models. HWI reminds the reader: “...it must be noted that all results derived from this investigation serve only to reveal potential correlations between OG development and raptor nesting activities; i.e., cause-effect inferences cannot be assumed.” HWI provides interpretations of those results deemed most important.

This overview contains more details from the results and discussion associated with Golden Eagle (*Aquila chrysaetos*) nests in the Price study area than for other species or for the Rawlins area. In this overview, information about other species and the Rawlins area is drawn largely from the report discussion. Please read the HWI report to learn about the methods used, to see many additional results, and to consider discussion of the results.

Price, Utah Study Area

The average density of OG wells proximate to raptor nest clusters increased three to four-fold at the 0.8 and 2.0-km scales from 1998–2006, and the average distance

to the nearest well decreased by roughly 20 percent. The number of nest clusters distant from wells was decreasing, and by 2006, 71 percent of nest clusters had no wells within 0.8 km and, 54 percent had no wells within 2.0 km.

Golden Eagle

HWI reports extensive results that reveal complex relationships among the factors included in their analyses. During the greatest OG development expansion (1999–2002), Golden Eagles used nest clusters that were farther from OG development hotspots than were unused clusters; however, this tendency diminished as new development subsided in the hotspots after 2002. This suggests that: 1) the development of new well sites temporarily deterred some Golden Eagles from nesting, and 2) some Golden Eagles habituated to established wells and associated maintenance.

Golden Eagle nest cluster use and activity varied between the 0.8-km and 2.0-km scale depending on development and vegetation factors, and with the Palmer Drought Severity Index (PDSI). Decreased drought severity, during a preceding year and the current year, was correlated with increased Golden Eagle nest cluster activity.

As more OG development occurred, Golden Eagle nest cluster use decreased, and nesting activity declined within 0.8 km. Golden Eagle nest cluster use increased within 2.0 km, as did activity within 0.8 km and 2.0 km, when there was a greater density of primary and secondary roads (i.e., roads that were not constructed to access OG well sites). A significant interaction existed between development factors and vegetation factors in models of the birds' nest cluster use and activity. For example, the models suggested that the probability of Golden Eagle nest clusters being used or active in May increased as:

- overall OG development decreased near clusters
- the prevalence of non-OG roads increased at the 2.0-km scale
- drought severity decreased
- cover of mountain, basin big, and black sagebrush increased
- pinyon and juniper decreased
- human infrastructure and rabbitbrush decreased

Between 1998 and 2006 the likelihood that a nest cluster was used was greater where the types of OG

development varied or where there was high diversity of OG development levels among alternative nests within clusters. This might be another indication that Golden Eagles respond differently to various types of development, and that when alternative nest sites exist, the birds can choose a site where they are less disturbed. Golden Eagle proportional nest use increased in areas of:

- mountain or basin big sagebrush, mountain shrub, conifer, and aspen, and high proportions of black sagebrush cover
- relatively high proportion of open water

Proportional nest use decreased in areas of:

- high pinyon-juniper and Wyoming or mixed-species sagebrush cover
- rabbitbrush, and riparian forest cover
- high human habitation

Golden Eagle proportional nest activity was greater in areas where

- extents of non-OG roads were more diverse at the 0.8-km scale among alternative nests within clusters
- cover of pinyon-juniper and barren lands within 2 km was low
- cover of desert shrub and agricultural habitats was relatively high

These proportional use models resulted in some relationships that when considered with other results reveal consistently positive factors (e.g., black sagebrush) and negative factors (e.g., human habitation) for Golden Eagle nest use and activity. HWI reiterated that the discrimination ability of the proportional use/activity models was low, and hence “these results must be considered with great caution.” However, these results reveal characteristics of the environment with which to experiment for enhancing nest use and activity.

Red-tailed Hawk

These results suggest that the probability of Red-tailed Hawk (*Buteo jamaicensis*) nest clusters being used increased in association with development within 0.8 km of the cluster, but decreased with OG development within 2.0 km. Additionally, use increased in habitats

dominated by a mix of mountain and basin big sagebrush cover, but decreased in habitats dominated by a mix of pinyon, juniper, and mixed-species sagebrush. The results for active clusters were similar and suggest that the relationships of development and nesting are modified by spatial scales and vegetation.

Prairie Falcon

Using only metrics of development, models of Prairie Falcon (*Falco mexicanus*) nest cluster use and activity data revealed no relationships to the development factors. Nest cluster use and activity were positively related to desert shrub and agricultural cover, but negatively related when relatively high cover of riparian forest, grass, forbs, and black sagebrush or pinyon, pinyon-juniper mix, and barren lands occurred. More activity at nest clusters was suggested with decreasing drought severity, but excessive winter precipitation might be detrimental.

Price area summary

HWI summarized some results as “patterns” for the Price study area, including:

- Price Golden Eagle data produced consistent negative relationships within 0.8 and 2.0 km of OG development.
- Red-tailed Hawk data produced mixed relationships with OG development; suggesting a benefit from some OG development within 0.8 km of nest clusters, but a diminished or reversed relationship to OG development within 2.0 km.
- The top Golden Eagle and Red-tailed Hawk model results suggested positive associations with non-OG roads, depending on the spatial scale.
- Use of the drought index revealed a generally positive effect of wetter conditions, as long as pre-nesting moisture was not extreme.

Rawlins, Wyoming Study Area

The number of wells increased from 1,438 to 4,258 between 1978 and 2006, most dramatically from 1978–1985 to 1994–2006. The total length of roads within 2.0 km of nest clusters increased significantly between 1978 and 2006, and the distance between nest clusters and OG wells decreased significantly, while the number of nearby wells increased significantly. The percentage of nest clusters with no wells nearby declined by 9 percent at the

0.8-km scale (from 95 percent to 86 percent) and 12 percent at the 2.0-km scale (from 86 percent to 74 percent).

Golden Eagles

The model using only development factors suggested that Golden Eagle nesting activity was negatively related to OG development within 0.8 and 2.0 km, and positively related with non-OG roads at the 2.0-km scale. Nest cluster use did not appear to be affected by development after accounting for vegetation and climate, although there was an indication that increasing OG development within 2.0 km of nest clusters was associated with decreasing nest activity. Integrating development, vegetation, and climate factors suggested that nest use and activity were:

- greater during periods of drought recovery
- positively related to greater cover of riparian forest, grass, mountain mahogany, agriculture, and less high-growing sagebrush species

The results from proportional Golden Eagle nest use and activity suggested that the proportion of years in which clusters were used or active increased:

- with relatively stable OG development,
- when alternative nests allowed eagles to change nesting locations relative to non-OG roads

Ferruginous Hawks

In the Rawlins study area, Ferruginous Hawks used a variety of nest substrates that included OG structures (mostly condensation tanks) and ANSs. Since 1987, the BLM has erected ANSs to discourage Ferruginous Hawks from nesting on oil and gas infrastructure.

Regarding nests that were not on ANSs, the models suggest that nest cluster use and activity were greater with less OG development and proportionately more non-OG roads within 0.8 km, but that these relationships diminished at the 2.0-km scale. When vegetation and climate were modeled with development, only nest-cluster activity in the 0.8-km radius of the nest had a negative relationship with OG development. Some use and activity models suggested a positive relationship with non-OG roads at the 0.8-km scale, but a negative relationship at 2.0-km. The positive relationships between non-OG roads within 0.8 km and non-ANS cluster use and activity increased when there was more

evergreen forest cover, but less Wyoming big sagebrush or agriculture. The proportional use and activity models also suggested a negative effect of OG development within 0.8 km of nest clusters, and a positive effect of non-OG roads at the 0.8-km scale.

Artificial nest structures often were erected within 1 km of where Ferruginous Hawks had constructed nests on OG facilities such as a condensation tank; thus, the majority of ANSs were near OG development. Ferruginous Hawk nest use and activity had a positive relationship with OG development at both spatial scales, and were positively related to non-OG roads at the 2.0-km scale. Positive relationships between OG development and ANS use and activity were enhanced by more riparian forest, grass, mountain mahogany, or agriculture. HWI notes, “Perhaps most importantly, compared to many natural-substrate nests, all ANSs were inaccessible from the ground and likely provided nesting birds with a sense of security in the face of development activities... inaccessible nests were nearly always successful, and therefore nearly all such nests were at least minimally productive.”

Red-tailed Hawks

Relationships between development alone and annual nest cluster use and activity indicated negative Red-tailed Hawk responses to OG development within 2.0 km of nests. Incorporating development, vegetation, and climate in models revealed that nest use was influenced by development levels, but nest activity was not. Red-tailed Hawk cluster use was negatively related to OG development within 0.8-km, but positively related at the 2.0-km scale, suggesting that the negative effects of OG development diminished with distance. However, cluster use was negatively related to non-OG roads within 2.0 km. Red-tailed Hawks in Rawlins also responded positively to reduced drought severity, and to greater cover of riparian forest, grass, mountain mahogany, and/or agriculture.

Prairie Falcons

Prairie Falcon nest cluster use and activity had a negative association with increased OG development and the extent of and proximity to non-OG roads. HWI suggests that Prairie Falcons might have been the most sensitive to general human activities of the four species it studied. When vegetation and climate variables were modeled with OG and development, the result again was a negative relationship of annual Prairie Falcon nest use and activity with OG development and non-OG roads. The negative association of OG development increased with more

barren land, but diminished with relatively high cover of Wyoming big sagebrush.

Rawlins area summary

Use or activity models for the four species in the Rawlins study area resulted in negative relationships at various scales with OG development factors, except for Ferruginous Hawk nesting on ANSs:

- Development and vegetation interacted variously among species and measurement scales to influence raptor nest use and activity.
- Vegetation relationships were complex for each raptor species, but all had positive relationships that suggest enhanced nesting in the presence of riparian forest, grass, mountain mahogany, or agricultural cover in the surrounding landscape, which might reflect productive bottomland, drainage areas, and agricultural uses.

Conclusions and Management Implications

The results from modeling only the relationships among raptor nest cluster use and nest cluster activity with development often differed from those resulting from including climate and vegetation variables in a model. This indicates the importance of considering factors of other human influences, vegetation, climate, etc., when evaluating the potential effects of OG activities near nests. HWI reminds the reader that the results are potential correlations between OG development and raptor nesting and that cause-effect inferences cannot be assumed.

HWI concludes that there were consistent results of negative relationships of OG development in the Price and Rawlins study areas after accounting for the occurrence of vegetation and climate conditions. Only Ferruginous Hawks using ANS exhibited consistent positive relationships among nest use and nest activity and OG development factors. The data were insufficient to determine if the apparent negative effects of development were associated with raptor population characteristics such as fledging young from the nest or a trend in numbers of nesting raptors.

HWI suggests that existing nesting-season protection buffers of 0.8-km radius should not be reduced, because the four focal raptor species exhibited negative relationships with OG development that occurred within 0.8 km of nest clusters. At the 2.0-km spatial

scale, negative relationships were found between OG development and Price-area Golden Eagles and Rawlins-area Golden Eagles and Prairie Falcons. The Golden Eagle results presented in this overview provide examples of the complexity of relationships among raptor nesting, OG development, and other environmental factors. As noted, these results reveal characteristics of the environment with which to experiment for enhancing raptor nesting. Many additional examples of results that provide a basis for developing additional management practices can be found in the report.

Artificial Nest Structures as Mitigation for Natural-Gas Development Impacts to Ferruginous Hawks (*Buteo regalis*) in South-Central Wyoming.

Mike C. Neal, Jeff P. Smith, and Steven J. Slater

Ferruginous Hawks were documented nesting on natural-gas structures in the Rawlins BLM district during the 1980s. Nests on structures such as condensation tanks commonly failed, so the BLM staff installed 105 artificial nest structures (ANS) from 1987 to 2004 to provide the hawks with alternative nest substrates. This report draws upon results presented in the lead author's thesis (M. Neal, University of Wyoming, 2007) and the previous Assessment report (above) to evaluate the efficacy of ANSs as a mitigation tool for Ferruginous Hawks nesting in areas of OG development.

HWI termed "active" nests as those where reproductive behavior (e.g., copulation, incubation, brooding, or nest attendance) was observed. Evidence of "occupied" nests included the observation of one or more hawks in the immediate vicinity of the nest or signs of hawk presence (e.g., recent nest material, prey remains) during the breeding season. From BLM records, HWI used 417 nest clusters and 1,234 nests in the analyses. Of these 1,234 nests, 750 (61 percent) occurred at 89 different ANSs, 88 (7 percent) at 13 other manmade nest substrates, and 396 (32 percent) at 315 natural-substrate nests (e.g., rocky-substrate, the ground on hillside, nests in evergreen-tree).

The nesting distribution of Ferruginous Hawks shifted to ANS, and active nests were closer to development-hotspot centers than inactive nests. Results from modeling indicated that nesting on other substrates only increased

in areas of low overall OG development and where primary and secondary road occurrence was high within 0.8 km but low at the 2.0 km scale.

HWI considered a nest or an ANS 2.5 m above ground to be inaccessible to human disturbance and predators. Accessibility was a predictor of nest success. The most "successful" category of nests was natural-inaccessible, followed by manmade-inaccessible, manmade-accessible, and least successful were accessible nests on natural substrates. HWI concluded that Ferruginous Hawks in the study area responded to ANSs and were successful on them, and this likely was due to ANSs providing a secure nesting location within foraging habitat that previously lacked secure natural nest sites.

The results from this research indicate that ANSs may be an effective mitigation tool where Ferruginous Hawks are nesting on inappropriate man-made structures, but HWI also suggests:

- Extensive use of ANSs could create a "population sink" wherein Ferruginous Hawks are attracted to nest sites, but then incur detrimental effects associated with use of the area.
- Studying post-fledgling survival, foraging-range habitat use, and long-term population growth and recruitment in comparison to an area where ANSs are not used.
- The extensive use of ANSs as mitigation must be accompanied by a long-term commitment to their maintenance to avoid a situation in which a large proportion of a nesting population becomes dependent on nest structures that eventually are unavailable.

Accipiter Use of Pinyon–Juniper Habitats for Nesting in Northwestern Colorado.

Steven J. Slater and Jeff P. Smith

BLM biologists documented nesting by three hawk species of the genus *Accipiter* in the Piceance Basin, Colorado in pinyon–juniper vegetation, which is an extensive cover type that previously had been largely overlooked as potential nesting areas for such species. The objectives of the HWI research were to survey for the hawks, and describe vegetation and landscape

characteristics of nests. Surveys involved broadcasting vocalizations of each species from stops along unpaved roads in areas of large stands of pinyon-juniper cover, and subsequent searches on foot to find new nest structures and visit historical nest sites.

Accipiters often flew toward survey stops before the birds were detected, and detections occurred as far as 540 m from nests. Nest-site characteristics of the three species commonly overlapped and each used pinyon and juniper trees for nesting in pinyon–juniper patches of at least 4.8 ha. The relatively small Sharp-shinned Hawk (*Accipiter striatus*), medium sized Cooper’s Hawk (*A. cooperii*), and large Northern Goshawk (*A. gentilis*) used nest sites with similar average canopy cover (64–65 percent) and densities of live trees between 23–38 cm DBH (168–175 trees/ha). Most commonly, nests were found on sloped terrain facing from northwest to east.

The surveys by the BLM and HWI have revealed an unexpected abundance of nesting accipiters in pinyon-juniper vegetation. Because federal lands are estimated to contain 65 percent of current pinyon-juniper cover, HWI recommends that accipiters be included when planning land management in this vegetation type. Recommendations for survey methods are provided in the report (p. 9-11).

Recommendations for Improved Raptor Nest Monitoring in Association with Oil and Gas Development Activities.

Jeff P. Smith, Steven J. Slater, and Mike C. Neal

The BLM and the DOE wanted to evaluate raptor nesting in areas of OG exploration and extraction. The BLM and industry had gathered information about raptor nesting occurrence and OG development, and HWI used this information and gathered new material for evaluating the relationships among development and raptor nest use. HWI found that some historical information was inadequate for use in addressing BLM and DOE interests.

Some of the problems HWI encountered to varying extents included:

- Terms and phrases used to label data often were not defined or used consistently within or among study areas.
- Inadequately documented (e.g., what was observed, when, or where) survey records.
- Lack of pre-development, baseline monitoring data.
- Little survey effort in areas not affected by that development (i.e., no control area data).
- Vague identification of nest locations.
- No report of the raptor species using the nest.
- Inconsistent data gathering (e.g., not surveying a nest cluster some years, not gathering the same information through time).
- A paucity of data about clutch and brood sizes.
- Insufficient information about the timing and extent of OG activities.
- Few current maps of existing road networks, accurate and current well-pad roads, and current powerline data.

The full report by HWI contains detailed recommendations to guide future monitoring of nesting raptors in conjunction with OG development. Included are key procedures that would facilitate more informative future evaluations:

- Training persons to conduct survey protocols.
- Regular use of Global Positioning System (GPS) technology.
- Budgeting time and personnel for regular entry of data and detailed metadata to electronic archives.

Implications From the Four Reports

Spatial and temporal buffer stipulations have contributed to raptor conservation in the study areas at Rawlins, Wyoming and Price, Utah where oil and gas development activities occur. The results of the HWI study reveal that OG operations near nests are associated with reduced raptor use and activity at nests in many circumstances. Sometimes the reductions of use and activity are temporary. Presumably, more disturbances would occur and there would be less habituation by raptors to disturbance if no restrictions had been placed on the distance and timing of OG operations near raptor nest sites. Consequently, there would have been greater reductions of use and activity than what has occurred. It could not be determined by HWI if there has been a change in the populations of raptors in conjunction with oil and gas development. Nonetheless, it can be concluded that applying spatial and temporal buffers around nests is a useful management practice to continue as part of a raptor conservation strategy.

Results from the four reports reveal many aspects of the environment that in combination with OG activities might influence raptor nesting, and thus have implications for management of areas where OG development is underway or where it might occur. Anthropogenic features other than those resulting from OG development, as well as vegetation cover and weather are associated with increases and decreases in raptor nest use and activity near OG activities. Whether or not the factors modeled were associated with more or less raptor nesting varied among species, study area, and measurement scale (within 0.8 or 2.0 km from nest).

The BLM can use results from the reports to further develop management strategies to conserve raptor nesting habitat near OG activities. For example:

- Develop survey designs with thorough, consistent methods for monitoring raptor nesting, and for monitoring factors that likely affect raptor nesting;

- Conduct surveys to document raptor nesting and associated environmental factors in areas unaffected by OG, especially areas where OG might occur;
- Implement survey and monitoring of select factors (species, vegetation, anthropogenic) at OG activity sites and at control sites;
- Gather raptor food habits data, and prey – vegetation association data and use results to manage habitat for prey;
- Conduct management to conserve and enhance existing vegetation that is presumed to be beneficial based on these HWI study results;
- Compare Ferruginous Hawk use of ANSs and associated survival and reproduction among ANSs in OG areas and non-OG areas;
- Provide ANSs for other species and evaluate their use and effectiveness as a mitigation method;
- Refine time and space stipulations by experimentally manipulating when and where OG activities occur relative to raptor nesting.

The mention of trade names or commercial products does not constitute endorsement or recommendation for use by the Federal Government.

These five documents are an integrated series.

BLM Technical Note 432

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BLM Technical Note 433

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Activities on Nesting Raptors in the Rawlins,
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BLM Technical Note 434

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